

Indications for anterior cervical decompression for the treatment of cervical degenerative radiculopathy

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Object. The objective of this systematic review was to use evidence-based medicine to identify the indications and utility of anterior cervical nerve root decompression.

Methods. The National Library of Medicine and Cochrane Database were queried using MeSH headings and key words relevant to surgical management of cervical radiculopathy. Abstracts were reviewed after which studies meeting inclusion criteria were selected. The guidelines group assembled an evidentiary table summarizing the quality of evidence (Classes I–III). Disagreements regarding the level of evidence were resolved through an expert consensus conference. The group formulated recommendations that contained the degree of strength based on the Scottish Intercollegiate Guidelines network. Validation was done through peer review by the Joint Guidelines Committee of the American Association of Neurological Surgeons/Congress of Neurological Surgeons.

Results. Anterior nerve root decompression via anterior cervical discectomy (ACD) with or without fusion for radiculopathy is associated with rapid relief (3–4 months) of arm/neck pain, weakness, and/or sensory loss compared with physical therapy (PT) or cervical collar immobilization. Anterior cervical discectomy and ACD with fusion (ACDF) are associated with longer term (12 months) improvement in certain motor functions compared to PT. Other rapid gains observed after anterior decompression (diminished pain, improved sensation, and improved strength in certain muscle groups) are also maintained over the course of 12 months. However, comparable clinical improvements with PT or cervical immobilization therapy are also present in these clinical modalities (Class I). Conflicting evidence exists as to the efficacy of anterior cervical foraminotomy with reported success rates of 52–99% but recurrent symptoms as high as 30% (Class III).

Conclusions. Anterior cervical discectomy, ACDF, and anterior cervical foraminotomy may improve cervical radicular symptoms. With regard to ACD and ACDF compared to PT or cervical immobilization, more rapid relief (within 3–4 months) may be seen with ACD or ACDF with maintenance of gains over the course of 12 months (Class I). Anterior cervical foraminotomy is associated with improvement in clinical function but the quality of data are weaker (Class III), and there is a wide range of efficacy (52–99%). (DOI: 10.3171/2009.3.SPINE08720)

KEY WORDS • cervical spine • foraminotomy • practice guidelines •
radiculopathy • surgery

Recommendations

Indications: Cervical Radiculopathy. Anterior surgical nerve root decompression via ACD with or without fusion in patients with cervical radiculopathy is recom-

mended for the rapid relief (within 3–4 months) of arm and neck pain, weakness, and/or sensory loss compared to PT or immobilization with a cervical collar. Anterior surgical nerve root decompression is recommended for longer term (12 months) improvement in wrist extension, elbow extension, and shoulder abduction, and internal rotation compared to PT. Other rapid gains observed after anterior decompression (diminished pain, improved sensation, and improved strength in certain muscle groups) are also maintained over the course of

Abbreviations used in this paper: ACD = anterior cervical discectomy; ACDF = ACD with fusion; ACF = anterior cervical foraminotomy; ADL = activity of daily living; CCI = cervical collar immobilization; NDI = Neck Disability Index; PT = physical therapy; VAS = visual analog scale.

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12 months. However, at the 12-month time point, comparable clinical improvements with PT or cervical immobilization therapy are also present in these clinical modalities. One caveat is that this recommendation is based on only 1 of several variables that may be important to the patient. Furthermore, there is insufficient data to factor in the cost of complications and any undesirable long-term effects related to the specific surgical intervention, such as adjacent-segment disease (quality of evidence, Class I; strength of recommendation, B).

Indications: Cervical Radiculopathy. Anterior cervical foraminotomy with attention to disc preservation is recommended in the treatment of cervical radiculopathy for relief of arm/neck pain, weakness, and/or sensory loss. However, conflicting evidence exists as to its efficacy with success rates of 52–99% reported. Recurrent symptoms have been reported in as many as 30% of patients (quality of evidence, Class III; strength of recommendation, D).

Methods. Methods will be addressed in the chapter on surgical techniques to treat anterior cervical radiculopathy.

Timing. There is insufficient evidence to make a recommendation regarding timing.

Rationale

Cervical radiculopathy presents with a combination of arm pain, sensory dysfunction, and motor function loss. Also common is associated neck pain. In the acute phase, nonoperative management is the mainstay, with success rates averaging 90%.¹⁶ Wainner and Gill²⁴ performed a systematic review of the diagnosis and nonoperative management of this disease and found that the course may often be favorable. However, these authors also noted that no clear prognostic factors had been delineated, nor had the efficacy of nonoperative therapy been well defined.²⁴

The purpose of this chapter is to provide an evidence-based review of the efficacy of anterior surgical nerve root decompression for radiculopathy. When clinical cervical radiculopathy is present with active nerve root compression visible on diagnostic imaging, the clinician often recommends surgical decompression if nonoperative measures have failed. Options for decompression include anterior or posterior approaches. The efficacy of posterior cervical nerve root decompression is reviewed elsewhere. The anterior approach has typically involved removal of the vast majority of disc material with or without subsequent fusion.^{3,15} Anterior cervical decompression without substantial disc removal or fusion has also been reported.^{2,9,23}

Search Criteria

We completed a search of the National Library of Medicine (PubMed) and the Cochrane Database for the period from 1966 through 2007 using both key words and associated MeSH subject headings. A search of “intervertebral disk displacement (Mesh)” and “cervical vertebrae (Mesh)” and “decompression, surgical (Mesh)” yielded 63

citations. “Anterior discectomy” and “outcome” yielded 296 citations. “Anterior cervical” and “decompression” yielded 890 citations. “Anterior cervical” and “decompression” and “outcome” yielded 335 citations. “Anterior cervical decompression” and “randomized trial” yielded 18 citations. “Anterior cervical discectomy” and “clinical trial” yielded 100 citations. “Anterior cervical foraminotomy” produced 58 citations.

For literature on cervical radiculopathy, we searched “radiculopathy (Mesh)” and “therapeutics (Mesh)” and “outcome assessment (Health Care),” which produced 83 citations. “Cervical radiculopathy” and “randomized controlled trial” produced 37 citations. We reviewed titles and abstracts with attention to those titles addressing trials comparing surgery to nonoperative management; we also found 1 Cochrane review that addressed the subject.

We selected articles if they clinically compared one treatment pathway to the other. We examined articles that contained information on only 1 technique if large numbers of patients were involved (typically > 40 patients) or if quantitative data were presented; this was decided on an ad hoc basis. We then compiled evidentiary tables (Tables 1 and 2) based on the resulting list of 23 studies that met our criteria. One randomized controlled trial and 1 systematic review examined ACD compared to PT or CCI (Table 1). The remaining studies examined large series pre- and postoperatively. The authors of 6 studies (Table 2) examined the technique of ACF.

Scientific Foundation

Critical Examination With Control Groups

Fouyas and colleagues⁵ completed a systematic review of surgery for cervical myeloradiculopathy. On completion of rigorous search and screening techniques, 2 articles met the criteria, 1 of which dealt with radiculopathy (the other was myelopathy). The authors completed appropriate tests for heterogeneity. The review used the random effects model to weight the treatment effects. It was uncertain how much weighting the random effects model achieved because only 1 study that analyzed radiculopathy was included. With respect to anterior decompression and radiculopathy, surgery appeared to improve pain (current) and sensory dysfunction at 3 and 4 months, respectively, compared to PT ($p < 0.05$) or CCI (pain, $p < 0.001$; sensory, $p < 0.05$). Compared to CCI, improvement was seen for “current” and “worst” pain. These effects dissipated at 1 year ($p = 0.5$) in all categories.⁵

The studies reviewed by Fouyas and colleagues⁵ were those of Persson et al.^{19,20} Using sealed envelopes, this study randomized 81 patients with cervical radiculopathy defined by clinical examination and radiological studies to surgery, PT, or CCI groups, 27 patients per group. Surgery was done via ACD with Cloward fusion. Evaluation was performed at 3–4 months after surgery and 12 months. This study evaluated patients clinically using the Mood Adjective Check List, Hospital Anxiety/Depression Scale, the Coping Strategies Questionnaire, VAS pain score, and the Disability Rating Index. The authors assessed strength using a dynamometer and a device to

TABLE 1: Evidentiary summary of studies examining anterior decompression through disc removal and outcome*

Authors & Year	Description	Results	Class	Conclusions
Fouyas et al., 2001	Systematic review of studies examining surgery for cervical myeloradiculopathy. Rigorous protocol of searching & screening.	2 studies dealt w/ radiculopathy & 1 w/ myelopathy. W/ respect to radiculopathy, surgery seemed to improve pain & deficits more quickly in the short-term (3 mos; $p < 0.05$) but results equal by 1 yr ($p = 0.2$).	I	Because many of the study parameters were equivalent at 12 mos (despite the significant clinical improvements w/ surgery at 3–4 mos), the authors concluded that the randomized trial did not provide enough reliable evidence on the beneficial effects of surgery for cervical radiculopathy.
Persson et al., 1997	81 patients w/ cervical radiculopathy (duration >3 mos) followed at 4 & 12 mos w/ VAS, hand strength dynamometer, & sensory testing. Randomized to surgery, PT, or CCI (n = 27).	Surgery group had improvement in mean current pain w/in group ($p < 0.01$); worst pain w/in wk was significantly improved w/ surgery or PT compared to CCI group at 4 mos ($p < 0.01$). No changes at 12 mos. At 4 mos, surgery had improved power relative to non-affected size in several muscle groups compared to PT or CCI. At 12 mos, this was true compared to PT only. Absolute muscle testing showed improvement at 4 mos w/ surgery compared to PT & CCI which did not persist at 12 mos. Paresthesias improved at 4 mos w/ surgery; improvement did not persist at 12 mos.	I	Surgery improves strength, sensation, & pain significantly at 4 mos. Improvement in pain & sensation does not significantly last after 4 mos. Class I: randomization w/ allocation concealment. Reliability for outcome tests.
Persson & Lilja, 2001	81 patients w/ chronic cervical radiculopathy (>5 mos), FU for 3–12 mos w/ MACL, HAD, CSQ. Pain measured w/ VAS & DRI. Randomized to surgery, PT, or CCI (n = 27 each) w/ FU at 3 & 12 mos.	Intention-to-treat analysis. Groups equivalent, but nonsmokers had less pain intensity ($p < 0.01$). W/ respect to pain intensity, surgery better than CCI at 3 mos ($p < 0.01$) but no group differences at 12 mos. MACL showed no group differences & no improvement. Age & duration did not correlate. Pain correlated w/ anxiety & depression in all groups over all time points. DRI showed surgery improved 'heavy work' & dressing persisting over 12 mos.	I	Chronic radicular pain associated w/ low mood state, anxiety, & depression which persist over 12 mos despite treatment. Coping was also poor. Surgery improved pain compared to collar but differences diminished at 12 mos. Class I study shows that surgery improves pain sooner but results similar at 12 mos w/ diminished chronic mood state.
Amasson et al., 1987	114 patients underwent either conservative (n = 33), anterior surgery (n = 37), or posterior surgery (n = 44). FU available for conservative (n = 24) or anterior (n = 35). Outcome was better, the same, or worse. Anterior surgery mostly ACD.	Local neck pain improved in 43% of patients w/ conservative & 55% of patients (only present in 29) w/ anterior surgery. Radicular pain improved in 19% of those w/ conservative (only present in n = 15) vs 71% w/ anterior surgery.	III	Anterior surgery is better than conservative therapy for anterior radiculopathy. Class III due to no statistics & selection bias. Surgeon & patients determined grouping & treatment.
Sampath et al., 1999	246 patients in CSRS study cohort w/ cervical radiculopathy; data were compiled from surveys of patients & physicians w/ outcome compiled from surveys.	Surgery recommended in 35% (86); FU in 155/246. FU in 51 (33%) surgery, & 104 nonoperative (67%). Pain scores improved in surgery & medically treated groups (1.6 vs 1.04). Neurological function improved 0.28 vs 0.64 (significant for surgery). Functional status measures improved in both medical & surgical patients (0.57). ADLs improved significantly in surgery group only.	III	Pain & functional status improves w/ medical & surgical treatment. Neurological function & ADLs improve more this surgery. Excruciating pain persisted in 26% surgery at FU. Class III: patients not randomized, treatment selected by physician. Uncertain whether patients were eligible for same treatment.

(continued)

TABLE 1: Evidentiary summary of studies examining anterior decompression through disc removal and outcome* (continued)

Authors & Year	Description	Results	Class	Conclusions
Klein et al., 2000	28 patients underwent ACDF for radiculopathy. Evaluation by Health Systems Questionnaire 2.0 at 21 mos. 1- or 2-level surgery, average age 44. Odom's criteria also used.	Significant improvements in physical function (p = 0.01), social function (p = 0.0004), physical role function (p = 0.0003), fatigue (p = 0.003), bodily pain (p = 0.0001). No difference in general health, mental health, or emotional role function. Good or better result in 93%.	III	Anterior decompression for radiculopathy is associated w/ improvement in physical & social function w/o overall general or mental health change. Class III. No reliability tested; no control group.
Bohlman et al., 1993	122 patients w/ radiculopathy as defined by arm pain and/or neurological deficit. ~ 60% had spondylosis. All treated w/ ACDF.	108 patients had good functional improvement w/ 81 having resolution of pain. Age, smoking, & Workers' Compensation status did not affect outcome.	III	Anterior decompression is effective therapy for cervical radiculopathy. Class III due to large case series.
Pointhillart et al., 1995	68 patients w/ cervical radiculopathy secondary to soft cervical disc herniation treated w/ ACDF. FU in 57 patients averaging 23 mos. Odom's criteria & radiographic outcome.	Good or better outcome in 92%; fusion in 33%; dynamic radiographs indicated only 2° of motion. Complications & reoperations in 3 of 57 who underwent FU.	III	Anterior decompression is effective therapy for radiculopathy from soft disc herniation. Class III due to large case series.
Brigham & Tsahakis, 1995	43 patients w/ radiculopathy w/ pain, dysesthesia, or weakness (duration 5.8 mos). Surgery ACDF for a mix of spondylosis & soft disc. 1-level (27) & 2-level (16). FU was 14 mos w/ Odom's criteria.	Good or better arm pain relief in 91% (excellent 77%). Neck pain relieved in 32/36 (82%). Minimal functional limitations in 93% (none in 77%). Complications related to graft in 3/43.	III	Arm pain & neck pain significantly improved w/ anterior decompression. Class III due to case series.
Heidecke et al., 2000	106 patients underwent Cloward fusion (145 levels) for radiculopathy (n = 28) or myeloradiculopathy (n = 78). Outcome 1, 3, 12 mos & 6.5 yrs w/ late questionnaire. Outcome also was judged good, fair, poor based on deficits.	Short-term pain improved in 26/28 (92.1%) & remained improved long-term (6.5 yrs). Satisfaction in 92.1%. Complications mostly pain related due to graft site.	III	Anterior decompression improves radiculopathy pain in >90%. Class III due to case series.
Gaetani et al., 1995	153 patients w/ cervical degenerative disease. Radiculopathy in 108 the vast majority of whom received ACD. FU 1-10 yrs using Odom's criteria.	Good or better outcome in 90.9%. Age, duration of symptoms, & disc pathology (soft vs rigid) did not affect outcome.	III	Anterior decompression is effective therapy for radiculopathy. Age & duration of symptoms do not correlate w/ outcome. Class III due to large case series.
Kozak et al., 1989	47 patients w/ cervical spondylosis & radiculopathy underwent ACDF. FU averaged 15 mos w/ 40/47 FUs.	Good or better outcome in 83% w/ fusion in 87%. Fusion status did not correlate w/ outcome.	III	Anterior decompression is effective therapy for cervical radiculopathy from spondylosis. Fusion status does not correlate w/ outcome. Class III due to large series.
Ylinen et al., 2003	71 patients w/ 1-level cervical disc disease who underwent ACDF; FU in 53 & compared to 53 healthy volunteers. Pain assessed w/ VAS, grip strength w/ dynamometer, & neck power w/ isometric.	Mobility (ROM) & isometric strength was diminished in the ACDF group (p < 0.001) compared to controls. Grip strength no difference (p = 0.16). 43% of ACDF patients had severe pain. Pain was associated w/ diminished ROM & strength.	III	ACDF is associated w/ diminished ROM & strength compared to normal controls. This can, occasionally, be associated w/ prolonged pain. Class III due to case-control series whose control did not have the underlying disease.
Lunsford et al., 1980	295 patients w/ cervical radiculopathy, soft disc (n = 101) or spondylosis (n = 194) treated w/ anterior decompression (ACD/135 or ACDF/108) w/ 253 FUs.	67% noted good or better results w/ 16% poor results. Outcome did not differ between soft or hard disc (p = 0.556). Recurrence of symptoms in 38% & did not differ between soft & hard disc (p = 0.897). However, only 4% of patients needed reoperation.	III	Anterior cervical decompression results in generally good improvement but moderate chance of recurrence of symptoms. Class III: selection bias due to uncertainty as to how patients were chosen for ACD or ACDF. Nonvalidated outcome measure w/o blinded observers.

(continued)

TABLE 1: Evidentiary summary of studies examining anterior decompression through disc removal and outcome* (continued)

Authors & Year	Description	Results	Class	Conclusions
Nandoe Tawarie et al., 2007	>400 patients w/ cervical radiculopathy who underwent ACD. FU over several years w/ questionnaire & chart review. NDI as FU.	FU at 6 wks indicated >90% of patients satisfied. Late phone survey FU in 102 patients w/ 67.6% having no recurrence of symptoms. However, 11% were worse. Complication rate was 10.3%. NDI would increase 0.75 points/yr on average.	III	ACD improves pain early but slow recurrence of pain develops over years. Class III due to series.
Peolsson et al., 2006	34 patients w/ cervical disc disease who underwent surgery; FU 6 mos through 3 yrs using VAS, NDI, DRAM.	28 available at 3 yrs' FU of whom 23 responded to questionnaire. VAS, neck pain, & numbness all improved (p < 0.02). No differences were evident at 3 yr compared to 6- & 12-mo results.	III	Improvement after anterior decompression; outcomes at 6 mos mirror outcomes at 3 yrs. Class III due to case series & poor FU.

* The criteria for scoring each manuscript into a class are described in *Introduction and Methodology: Guidelines for the Surgical Management of Cervical Degenerative Disease*, which appears in this issue of the *Journal of Neurosurgery: Spine*. Abbreviations: ADL = activity of daily living; CSQ = Coping Strategies Questionnaire; CSRS = Cervical Spine Research Society; DRI = Disability Index Rating; DRAM = Distress and Risk Assessment Method; FU = follow-up; HAD = Hospital Anxiety/Depression Scale; MACL = Mood Adjective Check List; ROM = range of motion.

measure pinch strength. The study used an intention-to-treat analysis and concealed allocation.^{19,20}

With regard to the questionnaires, the groups were homogeneous at the start although nonsmokers had less pain intensity (p < 0.01). Surgery reduced VAS pain intensity at 3 months more than CCI (p < 0.01); this effect was not seen at 12 months. The Mood Adjective Check List survey did not show any differences between groups and did not improve with therapy. The severity of pain correlated with the intensity of anxiety and depression in all groups on the Hospital Anxiety/Depression Scale and Coping Strategies Questionnaire. Finally, the Disability Rating Index showed that surgery improved return to heavy work and dressing ability better than the nonoperative alternatives at 12 months.¹⁹

With regard to current and worst pain, surgery or PT improved the “worst pain in last week” compared to CCI at 4 months (p < 0.01).²⁰ There were no significant differences between the PT, surgery, or CCI groups at 12 months. At 4 months, surgery improved power relative to the unaffected side in several muscle groups compared with PT or CCI. At 12 months, this difference was still present compared with PT. Absolute muscle strength improved with surgery at 4 months compared with both nonoperative alternatives. This difference did not persist at 12 months. A similar result was seen for sensory dysfunction.²⁰ These studies were scored Class I. Appropriate randomization and allocation concealment was undertaken. The groups were homogeneous at the start. The intention-to-treat analysis was used with minimal crossover. Finally, outcome assessments had good external reliability.^{19,20}

Arnasson et al.¹ and Sampath et al.²² completed comparative studies of lower quality. Arnasson and colleagues reported on 114 patients with cervical radiculopathy who underwent nonoperative treatment (33 patients), anterior decompression via ACD (37 patients), or posterior decompression (44 patients). For this review, the posterior decompression group was eliminated. Follow-up was completed in 24 patients in the nonoperative group and 35 in the anterior group. Clinical outcome was classified as better, the same, or worse. In those who had local neck pain, it improved in 43% of patients who received nonoperative treatment and 55% of those who underwent ACD. Radicular pain was only present in 15 of 33 patients who did not receive operative treatment, however, it improved in only 19% compared to 71% of patients who underwent ACD.¹ This study was Class III because of selection bias for each treatment arm, the poor follow-up for nonoperative patients, and the lack of statistical review.

Sampath et al.²² reported on 246 patients included in a cervical spine database from the Cervical Spine Research Society. In this cohort, the surgeons recommended surgery (anterior decompression with or without fusion in > 85%) for 86 patients (35%). Follow-up was only available for 155 patients (51 operative and 104 nonoperative). The study assessed outcome through questionnaires. Pain scores improved in both groups with an aggregate of 1.60 surgery versus 1.04 nonoperative. Neurological function improved 0.28 for the nonoperative group and 0.64 in the surgical group. This improvement was significant for the

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surgical group but not for the nonoperative group. Functional status improved in both groups significantly while ADLs significantly improved in the surgery group only ($p < 0.01$). However, the surgery group started with significantly worse ADLs (2.42 vs 1.88). This study was graded Class III due to the absence of randomization and selection bias and heterogeneity of the groups.²²

Case Series for Anterior Decompression

Several authors completed large case series (Class III) that reviewed the pre- and postoperative outcomes after anterior decompression for cervical radiculopathy.^{3,4,8,12,21} Klein et al.¹² reported a small study of 28 patients who underwent ACDF (1- or 2-level, average age 44 years) for radiculopathy. Evaluation was by the Health Systems Questionnaire 2.0 given at an average of 21 months. This study was included due to the quantitative data provided by the questionnaire. Odom's criteria were also used. Significant improvements were seen after surgery for physical function ($p = 0.01$), social function ($p = 0.0004$), physical role function ($p = 0.0003$), fatigue ($p = 0.003$), and bodily pain ($p = 0.0001$). However, no overall differences were seen for general health or mental health. Good or better outcomes were seen in 93% according to Odom's criteria. This study was graded Class III because external reliability was not tested and because there was no control group.

Bohlman et al.³ (122 patients), Pointillart et al.²¹ (68 patients), Brigham and Tsahakis⁴ (43 patients), and Heidecke et al.⁸ (106 patients) all reported series of patients with cervical radiculopathy who underwent anterior decompression surgery. In general, the vast majority of patients (339 total) did well. Odom's criteria were commonly applied, and good or better outcomes were generally seen in most patients (~90%). Complications were minimal in all 3 studies. In the Bohlman series,³ outcome was analyzed with regard to age, smoking status, and Worker's Compensation status. These did not appear to affect outcome.

Gaetani and colleagues⁶ and Kozak et al.¹⁴ also looked at certain prognostic indicators. Gaetani et al.⁶ reported on 153 patients, of whom 108 underwent ACD for cervical radiculopathy. Follow-up was over the course of 1–10 years using Odom's criteria. The authors observed a good or better outcome in 90.9% of patients. Age, duration of symptoms, and pathogenesis of disc herniation did not affect outcome. Because this was a series and it was not certain how homogeneous the cohort was, it was graded Class III.⁶ Kozak and colleagues¹⁴ reported on 47 patients with spondylosis and cervical radiculopathy who underwent ACDF with a 15-month follow-up using Odom's criteria for assessment. Forty of 47 patients responded to follow-up, and 83% were considered to have good or better outcomes. Fusion occurred in 87% of cases but did not correlate with clinical outcome. For similar reasons as the Gaetani et al.⁶ study, this study was scored Class III.

Ylinen et al.²⁶ compared outcomes in patients who had undergone anterior decompression for cervical disc prolapse to a healthy population who did not have radiculopathy or undergo cervical surgery. In this series, 71 patients with cervical radiculopathy underwent ACDF and

follow-up was available in 53. Outcomes in this group were compared to 53 healthy volunteers using a case-control technique. However, because the volunteers did not have the underlying disease, this study was graded Class III. Pain was assessed using the VAS, grip strength with using dynamometer, and neck power with isometric testing. Compared to the results in the healthy volunteers, mobility and isometric strength diminished after ACDF ($p < 0.001$). Grip strength was no different between the groups ($p = 0.16$). In the ACDF group, 43% of patients reported pain that was associated with diminished mobility and strength.

Lundsford and colleagues¹⁵ reported on 295 patients with cervical radiculopathy and soft disc displacement (in 101) or spondylotic ridge (in 194). Anterior decompression via ACD was achieved in 135 patients and ACDF in 108. Follow-up was reported for 253 patients. Using Odom's criteria, the authors reported a good or better outcome in 67% of patients, with a poor outcome in 16%. Outcome did not differ between patients with soft disc displacement and spondylotic ridge ($p = 0.556$). Over the study period, the authors observed recurrent symptoms in 38%, with repeated operations performed in 4%. Recurrence of symptoms did not differ between patients with soft disc and spondylosis ($p = 0.897$). This study was graded Class III because of selection bias as to how patients were chosen for surgery and nonvalidated outcome measures without assessor blinding.

Nandoe Tewarie et al.¹⁷ also reported recurrence of symptoms in a Class III case series. These authors reported on 456 of 551 patients with cervical radiculopathy who underwent ACD. Follow-up was conducted with a chart review, questionnaire, and telephone surveys. After 6 weeks, 90.1% of patients were satisfied with the outcome of surgery. Late follow-up by telephone in 102 patients revealed that 67.6% had no symptom recurrence. In those patients with symptoms, 20.6% (21 patients) had moderate complaints, while 11.8% (12 patients) had severe complaints. There was a postoperative complication rate of 10.5%.

Peolsson and colleagues¹⁸ found that early results at 6 months correlated to long-term outcome at 3 years using the VAS, NDI, and a distress questionnaire. In this Class III series, 34 patients underwent anterior decompression for cervical radiculopathy. Follow-up was available for 23 patients at 3 years. The VAS and NDI scores and numbness improved in all patients ($p < 0.02$). The results at 3 years were similar to those at 6 months. These authors did not report the recurrence rates described by Nandoe Tewarie et al.,¹⁷ however, this series was markedly smaller.

Anterior Cervical Foraminotomy

Jho et al.¹⁰ reported on 104 patients with cervical radiculopathy who underwent ACF. This cohort had an average age of 46 years and duration of symptoms of 17 months. Sensorimotor dysfunction was present in >60%, with similar proportions of soft disc (52%) and spondylosis (42%). The authors assessed outcome using Odom's criteria. The study reported good or better outcome in 99%, with an excellent outcome in 79.8%. The complication rate was ~5%. Using outcome measures from the

TABLE 2: Evidentiary summary of studies examining anterior foraminotomy (disc preservation) and outcome

Authors & Year	Description	Results	Class	Conclusions
Jho et al., 2002	104 patients w/ cervical radiculopathy who underwent ACF. Age 46 yrs w/ symptoms 17 mos duration. Sensorimotor dysfunction in >60%. Soft disc in 52% & spondylosis in 42%. Odom's criteria used for outcome.	Good or better outcome in 99% (79.8% excellent). Complication rate was ~5%. Using CSRS outcome, pain improved from 3.08 to 1.02 ($p < 0.00001$). Neurological rating improved from 2.97 to 1.68 ($p < 0.00001$). Functional status 1.78 to 2.02 ($p < 0.5$). ADL 1.80 to 1.27 ($p < 0.05$).	III	ACF associated w/ good outcome & improvement in pain & neurological function & ADL. Class III due to series.
Johnson et al., 2000	21 patients w/ cervical radiculopathy. All underwent ACF. Outcomes 12–42 mos w/ Oswestry Pain, VAS, radiography.	Oswestry improved in 91% from 64 to 83 ($p < 0.05$). Using VAS, good or better outcome in 85% (70% excellent) w/ 5% worse. No instability. Return-to-work of 95% light duty at 3 mos.	III	ACF improves pain in >85%. Class III due to case series.
Koc et al., 2004	19 patients (14 w/ 1-level op) w/ cervical radiculopathy who underwent ACF. Outcome by Odom's criteria & VAS.	Mean FU was 23.4 mos. Good or better outcome in 89.4% (excellent 78.9%). VAS improved from 5.2 to 1.7. No spinal instability developed.	III	ACF associated w/ improvement in pain & good functional outcome. Class III due to case series.
White et al., 2007	21 patients w/ 1- (n = 14) or 2-level (n = 7) cervical radiculopathy (1–48 mos duration) who underwent ACF. VAS completed by patient & surgeon for pain, strength, sensation. Patient & surgeon were blinded to each other's results (10–36 mos).	Pre- & postop assessment was fully complete in 67%. Mean VAS reduction in arm pain was 6.9 ($p = 0.0009$). Neck pain reduction 4.0 ($p = 0.0032$). Arm strength improved 3.8 ($p = 0.0086$), arm sensation improved by 3.8 ($p = 0.0032$). Surgeon thought 7.0 improvement in arm w/ minimal in neck.	III	Anterior foraminotomy relieves arm & neck pain subjectively. Class III due to series w/o control group & w/o blinded observation.
Aydin et al., 2005	216 patients w/ cervical degeneration and 182 w/ radiculopathy as defined by arm pain >3 wks or neurological deficit. Tx was "anterior contralateral approach." Primarily 1 level (75%) w/ soft disc herniation (~60%). Outcome w/ Odom's criteria.	Functional outcome was good or better in 100%. Motor recovery was seen in 92.9% & sensory recovery was 88.5%. 4 patients developed kyphosis & fibrous union w/o instability was seen in 92%.	III	Anterior contralateral limited discectomy is effective at pain relief & functional outcome. Class III due to large series.
Snyder & Bernhardt, 1989	63 patients w/ degenerative disease underwent anterior cervical fractional interspace decompression. FU averaged 23 mos. Odom's criteria applied.	Good or better results in 64–70% depending upon Worker's Compensation status. 87% returned to work. Spontaneous fusion in only 4%.	III	Anterior cervical decompression results in a good outcome w/ minimal complication. Class III due to case series.
Hacker & Miller, 2003	23 patients w/ cervical radiculopathy underwent ACF w/ 3-mo min FU.	7 patients (30%) underwent revision surgery: 4 due to recurrent disc & 3 due to intractable neck pain. Good or better outcome in 12 (52%).	III	ACF for decompression is associated w/ a high-revision rate w/ worse outcome (52%). Class III due to retrospective series.

Cervical Spine Research Society, pain improved from 3.08 to 1.02 ($p < 0.00001$). The neurological rating improved from 2.97 to 1.68 ($p < 0.00001$), functional status improved from 1.78 to 2.02 ($p = 0.5$), and ADLs improved from 1.80 to 1.27 ($p < 0.05$).¹⁰ This study was graded Class III because it was a case series and lacked a control group.

Johnson et al.,¹¹ Koc et al.,¹³ and White et al.²⁵ each described smaller, Class III series using a similar ACF technique. Johnson and colleagues¹¹ reported on 21 patients with cervical radiculopathy who underwent ACF. Follow-up was 12–42 months using an Oswestry Pain Scale, VAS, and radiographs. Oswestry Pain Scale and VAS scores improved in 85–91% of patients, with Oswestry values increasing from 64 to 83 ($p < 0.05$). The authors reported clinical worsening in only 5%. In the se-

ries of Koc et al.,¹³ 19 patients with cervical radiculopathy underwent 1- or 2-level ACF (14 and 5 patients, respectively). Outcome was evaluated using Odom's criteria and the VAS, with mean follow-up of 23 months. The authors reported good or better outcome in 89.4% (excellent in 78.9%). The VAS score improved from 7.9 to 1.7.¹³ White et al.²⁵ reported on 21 patients with cervical radiculopathy who underwent 1- or 2-level ACF, in 14 and 7 patients, respectively. The authors assessed outcomes by patients and surgeons using the VAS over 10–36 months. Follow-up was available in 67% of patients. The mean arm pain VAS score reduction was 6.9 ($p = 0.0009$), the VAS neck pain reduction was 4.0 ($p = 0.0032$), and arm strength ($p = 0.0086$) and sensation ($p = 0.0032$) each improved by 3.8. The estimate of the surgeon was similar that of the patient for arm pain.

Anterior cervical decompression for radiculopathy

Aydin et al.² and Snyder and Bernhardt²³ described modifications to ACF in 2 Class III series. Aydin and colleagues reported on anterior contralateral limited discectomy in 182 patients with cervical radiculopathy. Surgery was primarily at 1 level (75% of patients) with soft disc displacement in most (~ 60%). The authors assessed outcome using Odom's criteria, and reported good or better outcome in 100%. The authors reported recovery of motor function in 92.9% and sensory recovery in 88.5%. They reported kyphosis in 4 of 182 patients. The majority of patients (92%) developed fibrous union without instability. Snyder and Bernhardt²³ described 63 patients who underwent anterior fractional interspace decompression. Follow-up averaged 23 months and assessments were done with Odom's criteria. The authors observed good or better outcomes in 64–70% of patients, depending on Worker's Compensation status. The majority (87%) returned to work. Spontaneous fusion was observed in 4%.²³

Hacker and Miller⁷ described a series of 23 patients with cervical radiculopathy who underwent ACF with 3-month minimum follow-up. Seven patients in this series (30%) underwent revision surgery—4 because of recurrent disc displacement, and 3 due to intractable neck pain. Using Odom's criteria, these authors observed good or better outcome in 12 patients (52%). The evidence from this series was graded Class III.⁷

Summary

When comparing the results of anterior decompressive surgery to PT or CCI, Class I data indicates that surgery gives greater relief of neck/arm pain, weakness, and sensory loss at 3–4 months after therapy. Functional improvement appears to be longer lasting. Using Odom's criteria, the authors of multiple Class III series demonstrated good or better outcome in > 90% of patients after anterior decompression for cervical radiculopathy. However, Odom's criteria have problematic reliability and may be prone to conformational bias when assessed by the surgeon. Because of their subjective nature, Odom's criteria may not be readily reproduced by the same or different evaluators, leading to poor reliability. Furthermore, improvement or regression in Odom's criteria may not correlate with other outcome measures, resulting in suspect validity. Finally, its broad ranges make it poorly responsive. Accordingly, Odom's criteria are far from an ideal outcome measure.

Age, duration of symptoms, and type of disc pathology do not appear to play a role in outcome (Class III). One Class III study demonstrated that in patients who undergo anterior decompression for cervical radiculopathy, physical and social function—but not general health—appear to improve significantly. Another Class III study revealed that the 6-month outcome is similar to outcome at 3 years. However, the authors of 2 other Class III studies have suggested that recurrence of symptoms after several years is not uncommon in 11–38% of patients.

Multiple Class III series have indicated that ACF improves pain, weakness, and numbness, with neck pain improving in the majority. Good or better outcomes (Odom's criteria) were observed in 85–90% of patients. However,

1 Class III study concluded otherwise with revision surgeries in 30%, and good or better outcomes in only 52%. Given this conflicting data regarding ACF, no firm recommendations can be made.

Key Issues for Future Investigations

The advantage of anterior nerve root decompression lies in an operative approach to the pathology without crossing the neural elements. The theoretical disadvantage is loss of a motion segment if fusion is performed. Key issues include the ability to undertake anterior decompression without disc removal while minimizing the threat to the vertebral artery.

Future investigation should involve the identification of the ideal surgical treatment for soft lateral cervical disc displacement causing radiculopathy. Only 1 of the studies described above was a randomized controlled trial, and it contained only 81 patients. Review of the current peer-reviewed literature does not resolve whether anterior or posterior surgery yields better short- and long-term results, nor are there any trials comparing both of these groups to nonoperative therapy. Performance of a well-designed, randomized clinical trial in patients with this clinical scenario would enable resolution of this question.

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